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Improving Conceptual Model Development: Avoiding Underperformance Due to Project Uncertainties

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PURPOSE: Uncertainty in a project's outcome can result from gaps in data, insufficient knowledge about an ecosystem, or simple natural variability. Characterizing the effects of these uncertainties is a necessary step in effective conceptual model development. A clear procedure for integrating and visualizing this information can allow the Project Development Team (PDT) to efficiently compare and prioritize alternative formulations, thus improving probability of project success.

PROBLEM: Developing a project-specific conceptual model is a required step in creating any ecosystem restoration project plan regardless of project size (U.S. Army Corps of Engineers (USACE) 2005, 2008). A well-designed graphical or narrative conceptual model communicates connections between proposed restoration actions (e.g., notching a levee or adjusting river discharge patterns) and ecosystem attributes and responses (e.g., fish passage potential or spawning habitat quality or quantity). This project-specific conceptual model can be especially valuable for making links between project goals and opportunities and the formulation and comparison of alternative restoration actions. Factors that introduce uncertainty to the model can be loosely grouped into ***internal*** factors (e.g., assumptions about relationships among model components) or ***external*** factors (beyond project boundaries or proposed actions). Erroneous internal assumptions that can jeopardize project development are often linked to a lack of understanding about how a driver/stressor is linked to the desired ecosystem response. These are often due to:

Uncertainty can increase the probability of poor project performance

- Incomplete data on the ecosystem's structure.
- Incomplete understanding of how the ecosystem functions.
- Lack of clear connections between proposed actions and desired responses.

In addition to these internal uncertainties, there are also a variety of external moderating factors that can introduce uncertainty to a project, potentially jeopardizing realization of the sponsor's goals and stakeholders' expectations. In aquatic ecosystem restoration projects, these often include:

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- Ongoing changes in watershed hydrology due to regional climate shifts.
- Changes in biotic structure and function due to invasion by new plants or animals.
- Episodic effects of disease, fire, or other disturbance on biotic structure.
- Changes in watershed or geomorphology resulting from shifts in land use and urbanization.

To communicate and deal with either internal or external uncertainties, conveying the importance of (and the degree of uncertainty in) potential ecosystem responses to a proposed action through a project-specific conceptual model is critical to success in the review process. Beyond technical aspects, conceptual models benefit both the development of sponsor and stakeholder consensus on attainable goals and the comparison of alternative strategies for achieving those goals are key steps in project planning. This is especially important when working with partners from a range of agencies, backgrounds, or disciplines.

EXISTING GUIDANCE: The initial version of a conceptual model is most often developed in a workshop or series of workshops with the local sponsors, designers, planners, regulatory representatives, and other stakeholders that comprise the PDT. Basic project-specific conceptual model protocols and formats are widely available through the Ecosystem Restoration Gateway (*http://cw-environment.usace.army.mil/restoration.cfm*) and the Ecosystem Restoration Planning Center of Expertise (ECOPCX, *http://el.erdc.usace.army.mil/ecocx/*) (Henderson and O'Neil 2004, 2007a, 2007b; Fischenich 2008). Generally the conceptual model identifies the following components:

Displaying the driver-response links in a model is only a partial solution

- A clear statement of desired project goals and objectives.
- A list of ecosystem attributes of interest and drivers/stressors related to the goals and objectives.
- A graphical and/or narrative representation of how driver/stressor combinations influence the ecosystem attributes of interest.

The strengths and weaknesses of a project-specific conceptual model will vary depending on both the PDT and type of restoration actions being considered (Fischenich 2008). Figure 1 is an example in which hydrologic changes (the proposed restoration action) are meant to improve habitat (an intermediate essential ecosystem attribute) and subsequently enhance floodplain fish and bird productivity (the ecological response) in order to improve recreational hunting, fishing, and birding opportunities (the stakeholder and sponsor's desired goal). Examination of the conceptual model suggests that there are three potential types of hydrologic restoration that could each lead to the desired outcome: notching of levees, naturalizing the channel form, or naturalizing the river's hydrograph. Reaching stakeholder consensus regarding a range of proposed actions based on expected results is the PDT goal for model development. Level of detail and ability to communicate linkages is critical – most models will require careful interpretation for mixed audiences. In particular, Figure 1 does not explicitly relay information about relative likelihood of success of any of the three potential types of restoration. This could create a situation in which individual members draw their own, potentially conflicting, interpretations about project alternatives.

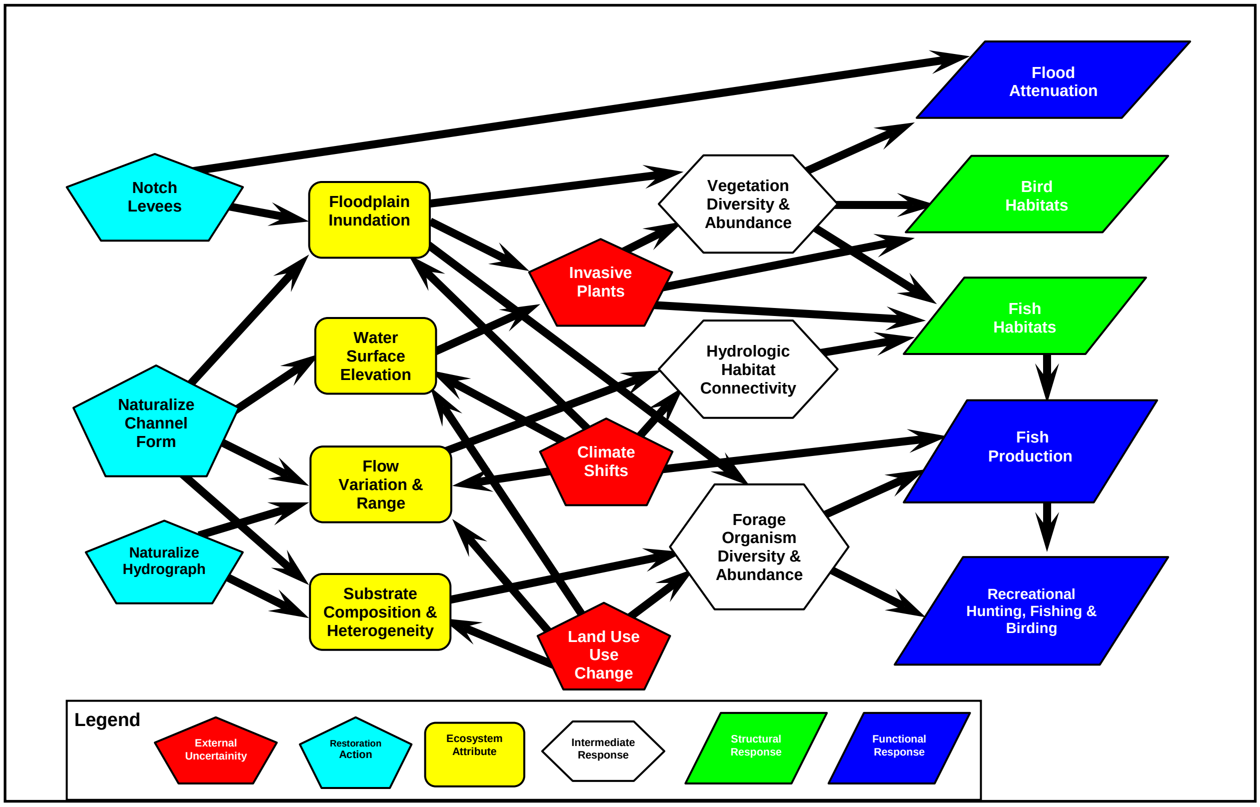

Figure 1. Example of a basic conceptual model for the restoration of fish and wetland diversity in a floodplain ecosystem project.

RECOMMENDED MODIFICATIONS: Existing guidance and many common model formats ***do not include*** approaches for communicating the importance or predictability of a particular driver/stressor relationship to the ecosystem. This means there is no way to determine which drivers are most likely to produce or prevent the desired outcomes.

Displaying data gaps can reduce uncertainty

The authors recommend modifying the current conceptual model format (e.g., Figure 1) to include additional information such as:

- Level of importance of each driver in affecting ecosystem attributes/responses.
- Level of understanding and predictability of driver-responses linkage.
- Value of additional empirical data to improve the understanding and predictability of the model and alternative restoration plan.

After adding this information to the conceptual model (Figure 2), different alternative action(s) might be selected if the desired response involves a driver of low importance, there is little understanding, or high unpredictability of the response. Three generalized questions can be used to develop this kind of information:

- What is the level of importance (e.g., high, medium, low) of each link between driver/action and response?

- How predictable is the relationship between driver/action and response (i.e., what is the strength of the correlation or mathematical relationship)?
- Are there important threshold values or feedback loops that need to be considered?

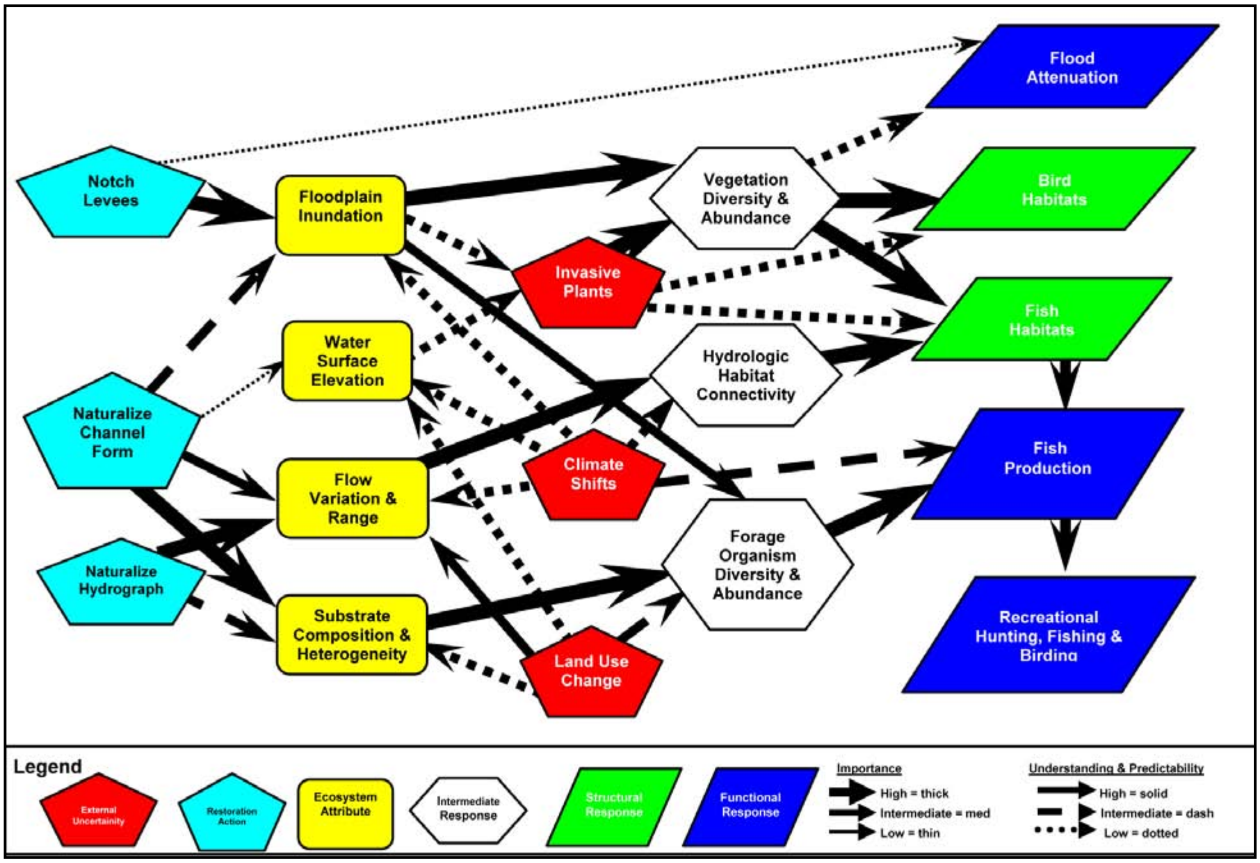

Figure 2. Floodplain conceptual model revised to include basic elements of relative importance, predictability/understanding for each set of driver-response linkages.

Note that in many conceptual model diagrams, risk and uncertainty are most often introduced to the restoration plan through assumptions about the numbers, strength, or importance of the links between actions/drivers and attributes/responses (i.e. via the arrows, not the shapes). The responses to these questions as well as any data or other rationale for modifying the conceptual model's information content also need to be captured in the planning documentation. If expert opinion and best professional judgment are used, then the minimum documentation would be a list of the experts queried, their basis for expertise (education, experience in the system, experience with the proposed restoration actions, etc.) and a list of questions and answers from the conceptual modeling workshop or process (see Burks-Copes et al. (in preparation) for greater detail). Alternatively, if a thorough literature review is used as the basis, then a written summary with full citation of supporting literature should be included in the report.

Acknowledging that there is some risk that a restoration project might fall short of desired goals can strengthen group consensus and management decisions. This happens when all parties understand that unpredictable or uncontrollable (external or internal) factors may affect proposed action(s) and thus influence the outcomes. Ultimately, appreciation of inherent uncertainty will

help prepare the PDT and stakeholders to modify either actions or expectations as the project proceeds – a form of proactive adaptive management.

IMPLEMENTING THE RECOMMENDED MODIFICATIONS: When linkages are shown by simple black arrows of uniform size, they only illustrate anticipated interactions between proposed actions and system components/responses (Figure 1). Conclusions about the performance of various restoration alternatives must be inferred from multi-step pathways. However, *this conceptual model shows that the desired attributes or responses (habitat and recreational opportunity) can be influenced by three or more actions or intermediate responses simultaneously. This demonstrates the type of ecological complexity that leads to uncertainty in predictions and alternative formulation, especially if relative linkage strength is not adequately described*. Without additional information on predictability and understanding of the driver-response relationships, the linkage arrows in Figure 1 provide little information about the relative importance of particular actions or pathways for comparison.

Additional driver-response information can clarify limitations and opportunities

The conceptual model can be improved by adding levels of predictability and understanding (Figure 2). If there is PDT consensus on the level of importance of driver-response links, then the conceptual model can be augmented to include predictability based on expert opinion, literature review, or empirical data collection (Figure 2). Many potential pathways are reduced to the three of highest importance and predictability; seen as the thick lines that pass through floodplain inundation, naturalize channel form, or naturalize hydrograph. For the PDT, these would be the three alternative action scenarios with the best chance of success. Additionally, the potential for external factors (e.g. invasive plants, climate shifts, and land use changes) to modify ecological responses is also more apparent. For example, notching supports bird and fish habitat through floodplain inundation and, subsequently, vegetation dynamics. However, floodplain inundation may also support invasive plants, which also have a strong but negative habitat effect (the dashed lines show a link but little understanding of it). Based on this conceptual model, the sponsors and stakeholders might decide that while levee notching is inexpensive, it also has a number of uncertainties. In contrast, the more expensive naturalized channel combined with invasive plant control actually has a better probability of attaining the project goals. A PDT response could be to include an invasive species management component to the restoration plan, thus reducing risks by acknowledging the uncertain but real effects of the invasive organisms.

There are several other examples of external factors that could affect the floodplain restoration project modeled in Figure 2. One is that although climate shifts could affect several of the proposed restoration actions and pathways, the strength and importance of the different interactions is unclear (i.e., there are many arrows, but all with a low degree of understanding or predictability). By acknowledging this, the PDT could then propose points in the project timeline at which the restoration activities could be modified in light of monitoring or assessment (i.e., adaptive management). In this way the effects of external stressors like climate can be addressed without revising or jeopardizing the restoration project's goals and objectives.

CONCLUSIONS AND RECOMMENDATIONS: Conceptual models are now strongly recommended for planning and adaptive management in Corps ecosystem restoration projects (USACE 2008). However, internal and external sources of model uncertainty can compromise both model functionality and, eventually, restoration project planning. Incorporating project-specific information about uncertainty into the conceptual model enables more thorough evaluation and communication about assumptions and risks. At a minimum, the PDT should develop consensus about potential improvements from evaluating the following:

- Data availability, completeness, and quality (empirical, literature, expert opinion).
- Importance and predictability of an ecosystem's components and drivers.
- External factors with moderating potential (e.g., shifting climate or land use).

This technical note provides a suggested modification of conceptual models to incorporate relative importance and uncertainty information with an example (Henderson and O'Neil 2007a, 2007b; Fischenich 2008). It should be stressed that this is not an all-purpose template. Rather, actual format and data requirements for a particular project are flexible and should be chosen based on specifically articulated project restoration goals. Adoption of this approach will benefit any restoration project. Technically it would strengthen links among metrics, monitoring, prediction/forecasting, and adaptive management portions of the planning process. From a project and program management point of view, the benefit is a fine tuning of visual/narrative format that effectively communicates limitations and opportunities to the public, project management, and the broader science and engineering communities of practice.

ADDITIONAL INFORMATION: Further details can be found in an on-line webinar on this and other topics at the Civil Works Environmental Gateway (*http://cw-environment.usace.army.mil/webinar.cfm?CoP=Env&Id=None*). This technical note was prepared by authors under the aegis of Environmental Benefits Analysis at the Environmental Laboratory, U.S. Army Engineer Research and Development Center, Vicksburg, MS. Invaluable input was provided by both Sarah J. Miller and Kelly Burks-Copes. Technical review was provided by Jock Conyngham and Burton Suedel of ERDC's Environmental Laboratory. This note represents one of seven protocols for improving planning, documentation, and, ultimately, implementation rates of Section 1135 and 206 ecosystem restoration projects. Environmental Benefits Analysis is a program sponsored by the Ecosystem Management and Restoration Research Program (EMRRP). For information on EMRRP, please consult *http://el.erdc.usace.army.mil/emrrp/emrrp.html* or contact the Program Manager, Glenn Rhett, at *Glenn.G.Rhett@usace.army.mil*. This technical note should be cited as follows:

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SOFTWARE AND INTERNET TOOLS: While first drafts of conceptual models can initially be formulated by hand, efficient revision and ultimate integration into all stages of project planning and management can be facilitated by existing software tools or GIS-based approaches like

those available at the online Conceptual Model Explorer website (*http://www.gomrc.org/tools.html*) developed by Gulf of Mexico Regional Collaborative (*http://gomrc.org/about.html*).

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